CHAPTER FIVE

TOTAL QUALITY MANAGEMENT
AS IT RELATES TO THE MANUFACTURING PROCESS

CONTENTS

TOTAL QUALITY MANAGEMENT AS IT RELATES TO THE MANUFACTURING PROCESS

OBJECTIVE

The key objectives of DOD's Total Quality Management (TQM) approach are to broaden the focus on quality and to change the present culture dealing with the acquisition process, contractual requirements, design and manufacturing practices, and the concept of acceptable quality. This Guide is concerned only with TQM as it relates to the manufacturing process.

INTRODUCTION

Quality means meeting all of the user's needs—cost, schedule, reliability, maintainability, and all of the other attributes that contribute to a system's value. Operational superiority of U.S. weapon systems is associated with a high degree of technical sophistication and superior performance. However, that superior performance would be to no avail if industry could not produce quality equipment free of defects and consistent in performance, durability, and reliability.

Quality (excellence) is a matter of culture and behavior. We must change those cultural aspects that impede production of high quality systems. DOD is working with the services and industry to identify the key approaches to enhance quality. Many excellent tools have been developed, but DOD has not been fully successful in implementing them. Dr. Robert B. Costello, the Undersecretary of Defense (Acquisition), signed a memorandum to the service acquisition executives which initiated implementation of a DOD Total Quality Management approach. This memorandum strongly states that DOD is committed to taking a leadership position.

The TQM process is a total organizational approach to continuous improvement of quality and productivity. TQM requires management to exercise the leadership to establish the environment for the process to flourish. It involves an integrated effort toward improving performance at every level. This improved performance must satisfy goals of quality, cost, schedule, mission need, and suitability focusing on increased customer/user satisfaction.

To meet this challenge, DOD and industry must redirect the work force, change management styles, implement new processes, and most important, listen to employees, as well as their customers, the operating forces. Management must create the climate to establish challenging goals and to ensure that the work force is properly motivated. Tangible actions are necessary to stimulate changes.

Improvements in quality can provide the highest return on investment, because they involve the efficient use of existing people and material resources. The reduction of errors at every level reduces costs and improves the effective use of resources. Quality does not cost; it pays.

TOTAL QUALITY MANAGEMENT OVERVIEW

TQM is the application of methods and human resources to control the processes that produce defense materiel, with the objective of achieving continuous improvement in quality. The DOD TQM strategy also addresses the concurrent need to motivate U.S. industry to greater productivity. It is a strategy for improving the quality of DOD processes and products and achieving substantial reductions in the cost of ownership throughout a system's life cycle.

TQM draws on a rich heritage of research and experience reaching back to the development of Statistical Process Control (SPC) during World War II. The many distinguished scientists, engineers and practitioners have contributed to the rich body of knowledge include: Dr. Walter A. Shewhart (SPC), Drs. Harold F. Dodge and Harry Romig (Sampling), Ellis R. Ott (Process Quality Control), Eugene L. Grant (Statistical Quality Control), Dr. Amand V. Fiegenbaum (Total Quality Control), Dr. Joseph M. Juran (Industrial Quality Control), Dr. W. Edwards

Deming (Quality and Productivity Management), Philip B. Crosby (Quality College), Genechi Taguchi (Experimental Design), Dr. Kaoru Ishikawa (Cause/Effect Diagrams), Shigeo Shingo (Low-cost, high quality production).

At the current time, much of the implementation of TQM within American industry is being accomplished within the context of the "Fourteen Management Principles" of Dr. W. Edwards Deming. These points are shown in Figure 5-1.

- CREATE CONSTANCY OF PURPOSE FOR IMPROVEMENT OF PRODUCT AND SERVICE
- ADOPT THE NEW PHILOSOPHY
- CEASE DEPENDENCE OF INSPECTION TO ACHIEVE QUALITY
- END THE PRACTICE OF AWARDING BUSINESS ON BASIS OF PRICE TAG ALONE
- CONSTANTLY AND FOREVER IMPROVE THE PROCESS OF PLANNING, PRODUCTION, AND SERVICE
- INSTITUTE MODERN METHODS OF TRAINING ON THE JOB
- INSTITUTE MODERN METHODS OF SUPERVISION
- DRIVE OUT FEAR
- BREAK DOWN BARRIERS BETWEEN STAFF AREAS
- ELIMINATE SLOGANS, EXORTATIONS, AND TARGET FOR THE WORK FORCE
- ELIMINATE NUMERICAL QUOTAS FOR THE WORK FORCE AND NUMERICAL GOALS FOR MANAGEMENT
- REMOVE BARRIERS THAT ROB PEOPLE OF PRIDE OF WORKMANSHIP
- INSTITUTE A VIGOROUS PROGRAM OF EDUCATION AND SELF-IMPROVEMENT
- PUT EVERYBODY IN THE COMPANY TO WORK TO ACCOMPLISH THE TRANSFORMATION

Figure 5-1 The Fourteen Management Principles of Dr. Deming

The TQM concept embraces the effective integration of existing management initiatives and initiation of new techniques that have a positive impact on quality. Examples are: acquisition streamlining, statistical process control, continuous process improvement, value engineering, transition from development to production, warranties, gain sharing, Taguchi methods of experimental design, quality function deployment (QFD), simultaneous engineering and concurrent design; variability reduction and just in time, group technology or cellular methods for shop operation.

The non-technical aspects of TQM include process improvement methodology including problem solving techniques, performance measurement techniques, reward and recognition system, team operating principles; dedicated, knowledgeable facilitators; intensive training; cross functional TQM teams; user and customer involvement and feedback.

TQM is implemented by obtaining top-level commitment to TQM in both DOD and industry. It requires extensive training, review and reform of contract related policies and practices (e.g., FAR, specs and standards, administrative procedures) to radically change the acquisition culture. Pilot applications and contractor participation efforts are currently underway and much is being learned about the effectiveness of various approaches.

Current Environment

A 1987 Gallup Survey of Chief Executive Officers' views on quality revealed some disturbing conclusions. The survey found that while 81% of the CEOs laid claim to "visible top management commitment for total quality" and 63% claimed to use TQM "very often or often", only 38% of the companies used hourly employee involvement teams, only 39% used salaried involvement team, and only 45% used statistical process controls. Well over 50% of the CEOs felt that their company's cost of quality (COQ) was under 5%. Experts calculate the average COQ at 20-30% of sales. What is particularly frightening is that many CEOs don't know what percentage of their business is dedicated to avoiding waste and don't feel comfortable at guessing at a number.

This cost in terms of internal and external failures, prevention cost and appraisal costs is often 20% or more of DOD contract dollar value. This does consider reductions in performance, availability, reliability and maintainability that result from quality problems. While many contractors claim to have TQM systems, there has not been much improvement in product quality or integrity. Air Force Contract Management Division continues to find problems during their Contractor Operations Reviews, similar to those that they have found and documented in the past. The Defense Logistics Agency continues to find excessive rates of waivers and deviations, often in excess of 40%. This would indicate that problems exist in prevention, that industry is not building quality into DOD products and services. A recent "should cost" review documented that 45% of testing is really re-testing and that 80% of sustaining engineering is dedicated to Material Review Boards (MRB) and failure analysis.

This must be changed. One way is through greater use of process control in place of product inspection. An example is the Air Force Variability Reduction Program (VRP) to improve combat capability through defect reductions. The objective of VRP is to design and build to target value specifications rather than tolerances. These values are directly related to achieving the user's operational requirements. As the manufacturing process becomes more capable, the yields increase as defects decrease.

Good Enough Versus Continuous Improvement

For a long time, DOD followed the concept of "minimum acceptable" quality. America's manufacturers and DOD maintenance depots have pursued this concept with the resignation that a persistent level of errors, perceived as irreducible, was a way of life. This concept was a major contributor to high failure rates and the escalating cost of repairs. DOD cannot tolerate this concept if it intends to maintain a leadership role among industrial nations.

Previous DOD quality programs focused on inspection, or ensuring conformance to requirements. Total Quality Management changes the focus of quality from inspection to continuous process improvement. The essence of this approach is providing the impetus for improving requirements, design, and manufacturing processes.

Manufacturers must implement rigorous and effective defect prevention process control programs. The process operation should continuously strive for improvement rather than accept a predetermined level of defects. By building a series of quality checks into the process, all imperfections will eventually be screened out and corrected during the process. This approach will dramatically change the prevailing mind-set and be pivotal in the cultural change being advocated.

Unfortunately, in the past DOD accepted inefficient work and rework as a normal state of affairs. Yesterday's errors became the basis for planning today's contracts. Responses to some RFPs for production contracts have shown that 30 to 40% of the fabrication and assembly cost is for reprocessing. Forty-five percent of the test cost is for equipment and labor to troubleshoot and retest failed items. These figures are based on the time expended on contracts for correction of errors.

DOD uses specifications and standards to impose contractual requirements. These documents are essential to the acquisition process because they provide the baseline for the proposal and source selection process, as well as the legal basis to determine contractual compliance. One of the requirements found in these documents is Acceptable Quality Level (AQL) or the Lot Tolerance Percent Defective (LTPD). These provisions were originally intended to institute standard sampling procedures to ensure quality integrity of large production lots. Such numerical values, however, have been used by many manufacturers to justify lack of action in instituting effective process controls to improve quality. These contractors have accepted the “good enough” concept, and have lost sight of good business practices aimed at customer satisfaction. Allowing a persistent level of errors as a way of life has contributed to unacceptable failure rates in defense equipment and to the escalating cost of maintenance and logistic support.

The DOD, to rectify the perception of allowable defects and stimulate changes to improve product quality, has recently directed its specification preparing activities to remove AQLs and LTPDs as fixed requirements in military product specifications. This action will provide opportunities to improve quality to the maximum extent possible by promoting competition based on excellence.

Intricate sampling plans based on prescribed AQLs required the inspection of products to determine acceptance, thereby relieving the contractor of further responsibility for quality. The new approach recognizes the value of sampling inspection techniques as a quality assurance tool. It removes, however, the inference that a predetermined amount of defects are expected and allowable. It enforces the concept that all delivered products are expected to comply with the established technical requirements.

Contractors must institute effective process controls and in-process inspection techniques that preclude out-of-tolerance conditions during manufacturing in order to achieve continuous improvement and the ability to compete on the basis of quality. By stabilizing the process well within acceptable limits, the “defect-detection” approach is replaced with the “defect prevention” technique. The latter does not leave the process to chance and then require screening of the good from the bad at the end of the process, nor does it rely exclusively on a sampling inspection that offers a measure of the degree of non-compliance.

The procurement system must become more flexible. Designers must work closely with manufacturing engineers and logisticians. This team must develop producible designs that meet performance expectations and are affordable. DOD has already created such teams in the Office of the Secretary of Defense, with members from research and advanced technology, production, and logistics.

TQM is essential to achieve these goals. Therefore, contracts should be awarded to companies whose products and services reflect the application of TQM and who have demonstrated outstanding reliability. Recent changes to the FAR require that quality be considered as a factor in source selection.

PRINCIPLES OF TOTAL QUALITY MANAGEMENT

TQM is a term in general use, although there is no specific agreed-upon definition within DOD. The five principles of TQM have been identified as follows:

- User satisfaction; meet your customers’ requirements
- Problem prevention - not problem detection
- Continuous process improvement
- Innovation in products, processes and services
- Involve everyone

The focus of the TQM efforts are directed toward assuring that the systems and equipment provided to the operational forces have, and will continue to have throughout their life span, performance characteristics which satisfy the required level of military capability.

These directions need to be interpreted within the structure of the DOD TQM approach and the DOD Posture on Quality shown in Figure 5-2.

TOTAL QUALITY MANAGEMENT TOOLS

Total Quality Management requires the synergistic interaction between management philosophy and procedures, and quality technologies. No single checklist or formula can be developed to institutionalize this philosophy in the DOD procurement community.

- QUALITY IS ABSOLUTELY VITAL TO OUR DEFENSE, AND REQUIRES A COMMITMENT TO CONTINUOUS IMPROVEMENT

* A QUALITY AND PRODUCTIVITY ORIENTED DEFENSE INDUSTRY, WITH ITS UNDERLYING INDUSTRIAL BASE, IS THE KEY TO OUR ABILITY TO MAINTAIN A SUPERIOR LEVEL OF READINESS

- IMPROVEMENTS IN QUALITY PROVIDE AN EXCELLENT RETURN ON INVESTMENT AND, THEREFORE, MUST BE PURSUED TO ACHIEVE PRODUCTIVITY GAINS

* TECHNOLOGY, BEING ONE OF OUR GREATEST ASSETS, MUST BE WIDELY USED TO IMPROVE CONTINUOUSLY THE QUALITY OF DEFENSE SYSTEMS, EQUIPMENTS AND SERVICES

* QUALITY MUST BE A KEY ELEMENT OF COMPETITION

* ACQUISITION STRATEGIES MUST INCLUDE REQUIREMENTS FOR CONTINUOUS IMPROVEMENT OF QUALITY AND REDUCED OWNERSHIP COSTS

- MANAGERS AND PERSONNEL AT ALL LEVELS MUST BE HELD ACCOUNTABLE FOR THE QUALITY OF THEIR EFFORTS

- COMPETENT, DEDICATED EMPLOYEES MAKE THE GREATEST CONTRIBUTIONS TO QUALITY AND PRODUCTIVITY. THEY MUST BE RECOGNIZED AND REWARDED ACCORDINGLY

- QUALITY CONCEPTS MUST BE INGRAINED THROUGHOUT EVERY ORGANIZATION WITH THE PROPER TRAINING AT EACH LEVEL, STARTING WITH TOP MANAGEMENT

- PRINCIPLES OF QUALITY IMPROVEMENT MUST INVOLVE ALL PERSONNEL AND PRODUCTS, INCLUDING THE GENERATION OF PRODUCTS IN PAPER AND DATA FORM

- SUSTAINED DOD-WIDE EMPHASIS AND CONCERN WITH RESPECT TO HIGH QUALITY AND PRODUCTIVITY MUST BE AN INTEGRAL PART OF OUR DAILY ACTIVITIES

Figure 5-2 DOD Posture on Quality

TQM must be based upon a recognition of the need for interactions between various disciplines. There is a natural tendency to search for the solutions to a problem within one's own discipline. For example, some promote the view that management commitment is the key to a successful TQM. Others focus on the use of quality technology. Any myopic view is disastrous in TQM because it is a team effort. Management must have a conceptual understanding of quality technology including statistical thinking and tools. Technical personnel must understand management's role and limitations. DOD managers, both in industry and government, must perform within the framework of DOD acquisition laws and regulations. Also, statisticians and other quantitatively trained personnel must avoid the pitfall that statistical thinking and tools are the total solution. The use of statistical techniques is certainly necessary, but definitely not the single sufficient condition for success. Experience has shown that use of statistics has a limited impact unless its use is supported by a larger system such as TQM. By institutionalizing TQM, the DOD program managers can help ensure the proper role and use of quality technology. Thus, TQM tools do not merely include statistical methods, but also include concurrent engineering, computer applications, CAD/CAM systems, producibility analysis, data-management and analysis systems, value engineering, transitioning from development to production templates, and several other techniques outlined in the various chapters of this guide.

This section will focus upon the TQM tools pertaining to quality technology.

Basic Tools of Statistical Process Control(SPC)

One key element of the continuous quality improvement concept is process control. For many manufacturing processes, statistical process control (SPC) is most effective. SPC is based on the premise that all processes exhibit variation; in other words, it is an analytical technique for evaluating the processes and taking action based on stabilizing the process within the desired limits.

SPC is one of the most widely used statistical quality control techniques in the United States. Two things have caused this to happen: first, the rediscovery of the works of Dr. W. Edwards during the early 1980's; second, the major push for SPC brought about through applications in the automobile industry.

SPC is an operator's tool. It assists the operator in making timely decisions about the process: adjust, leave alone, or shutdown and take corrective action before defects are produced. SPC provides evidence of how a process is performing. SPC helps distinguish between patterns of natural variation (expected), and the non-desirable, unexpected variations (assignable to malfunction). SPC provides a better understanding of how the processes affect the products. Assurance of conformance is, therefore, obtained through defect prevention by control of the various processes, rather than after the fact. Clear understanding of the causes and extent of variation can also be used as a basis for reducing the process variability, thus improving the quality of the output.

The Japanese have trained a large portion of their work force in the use of seven basic quality control tools. These are also sometimes referred to as the elementary SPC tools and are used by the production workers to solve day-to-day shop floor quality problems, mainly through their quality improvement teams and employee suggestion systems. The number of suggestions turned in by Japanese workers is legendary. While the average number of suggestions per employee per year in the United States is 0.1, the figure in Japan is 10. More important, over 80% of the worker suggestions are approved by the Japanese management. This is mainly because Japanese workers are trained in the basic tools of quality control and thus experiment with their own ideas, pilot runs, and submit their suggestions to management only when they are reasonably sure of success. Thus, instead of having a few professionals to tackle problems, they have an army of problem solvers. The following is an outline of the objectives and methodology for each of the seven (7) basic quality control tools:

1. P.D.C.A. (Plan, Do, Check, Act)

   The PDCA cycle is a problem solving tool by trial and error and consists of the following iterations:

   - Plan the Work

- Execute
- Check Results
- Take action if there is a deviation between desired and actual results
- Repeat the above cycle until deviation is reduced to zero.

This tool is used mostly by production workers and whenever more powerful techniques are unknown or unsuitable.

2. Data Collection and Analysis

This is generally the first step in identifying and reducing the variation in any process. The major steps involved are:

- Define specific reasons for the collection of data
- Decide on measurement criteria
- Assure accuracy of measuring equipment (minimum 5 times greater than product requirement)
- Randomize and stratify data collection (time, material, machine, operator, type and location of defects)
- Analyze data using several SPC, or Design of Experiments (DOE) tools.

3. Graphs/Charts

The most common types of graphs/charts are bar charts, line charts, and pie charts. These are tools for the organization, summarization, and statistical display of data. Their main objective is to display trends, reduce data, or communicate and explain data. It is important that the purpose of using graphs or charts be clearly established and the usefulness periodically examined.

4. Check Sheets/Tally

Sheets/Histograms/Frequency Distribution Diagrams

There are several types of check sheets: for process distribution, for defective items, causes, defect locations (sometimes referred to as "measles charts"), and as memory joggers for inspectors while checking products. Their main function is to simplify data gathering and to arrange data for statistical interpretation and analysis.

Histograms and frequency distributions provide a graphical portrayal of variability. Their shape often gives clues about the process measured, such as mixed lots (bimodal distribution); screened lots (truncated distribution); amount of spread relative to specifications; non-centered spread relative to specifications. There are two general characteristics of frequency distributions that can be quantified—central tendency and dispersion.

5. Pareto's Law

Vilfredo Federico Pareto was a nineteenth-century Italian economist who studied the distribution of income in Italy and concluded that a very limited number of people owned most of its wealth. The study produced the famous Pareto-Lorenz normal distribution law, which states that cause and effect are not linearly related; that a few causes produce most of a given effect; and, more specifically, that 20% or less of causes produce 80% or more of effects.

Dr. Joseph M. Juran, however, is credited with converting Pareto's law into a versatile, universal industrial tool applicable in diverse areas, such as quality, manufacturing, supplier materials, inventory control, cycle time, value engineering, sales and marketing. In fact, in any industrial situation, by separating the few important causes from the trivial many, work on the few causes can be prioritized. Figure 5-3 is a typical example of a Pareto chart and its usefulness. Three items, which alone accounted for $2,800 per month of loss (or over 80% of the total loss) as shown in (a), were prioritized and reduced to $1,400 per month as shown in (b), before the remaining problems were resolved.

6. Ishikawa Diagram

This technique was developed by Dr. Kaoru Ishikawa, one of the foremost authorities on quality control in Japan. The Ishikawa Diagram is also known as cause-and-effect diagram or, by reason of its shape, a fishbone diagram. It is probably the most widely used quality control tool for problem solving among blue-collar workers in Japan. While it is a relatively simple tool, its effectiveness is less than optimal. This is mainly because it allows only one cause to be varied at a time and thus, the interaction effects are missed, which in turn results in only partial solutions and, thus, less than optimal improvement in quality.

Figure 5-4 is an example of a cause-and-effect diagram, listing all the possible causes that can produce solder defects in a wave solder process. (For the sake of simplicity, only two major branches: machine and machine materials are shown. Figure 5-4 is an excellent compilation of all the variables that can cause a solder defect. It also highlights with circles those variables judged to be important.

7. Control Charts

In the minds of some quality professionals and nonprofessionals alike, the control chart is synonymous with SPC. In reality however, control charts are simply a maintenance tool. Their main function is to maintain a process under control, once its inherent variation has been established and minimized. The most common misuse of control charts is put them into effect in order to solve problem. If there is a known problem, the application of control charts will not solve it. It will simply confirm that a problem exists. Any improvement must come by reduction in the inherent variation in the process. This can be accomplished in a limited fashion by simple tools such as brainstorming and cause and effect diagram; or, more effectively through the use of sophisticated Design of Experiments.

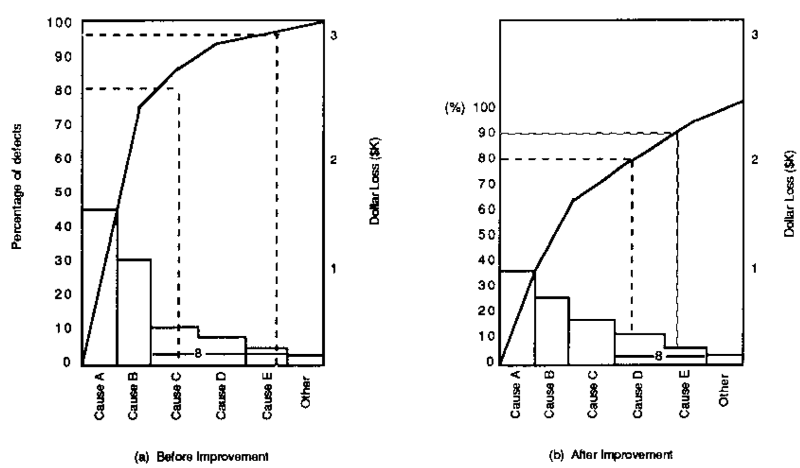

Figure 5-3 Examples of Pareto Chart Before and After Improvement

Design of Experiments (DOE)

The main objectives of Design of Experiment (DOE) techniques are to:

- Identify the important variables' whether they be product or process parameters, materials or components from suppliers, environmental or measuring equipment factors.
- Separate these variables into one to four important variables.
- Reduce the variation on the important variables (including the tight control of interaction effect) through close tolerancing, redesign, supplier process improvements, etc.
- Open up tolerances on the unimportant variables to reduce cost substantially.

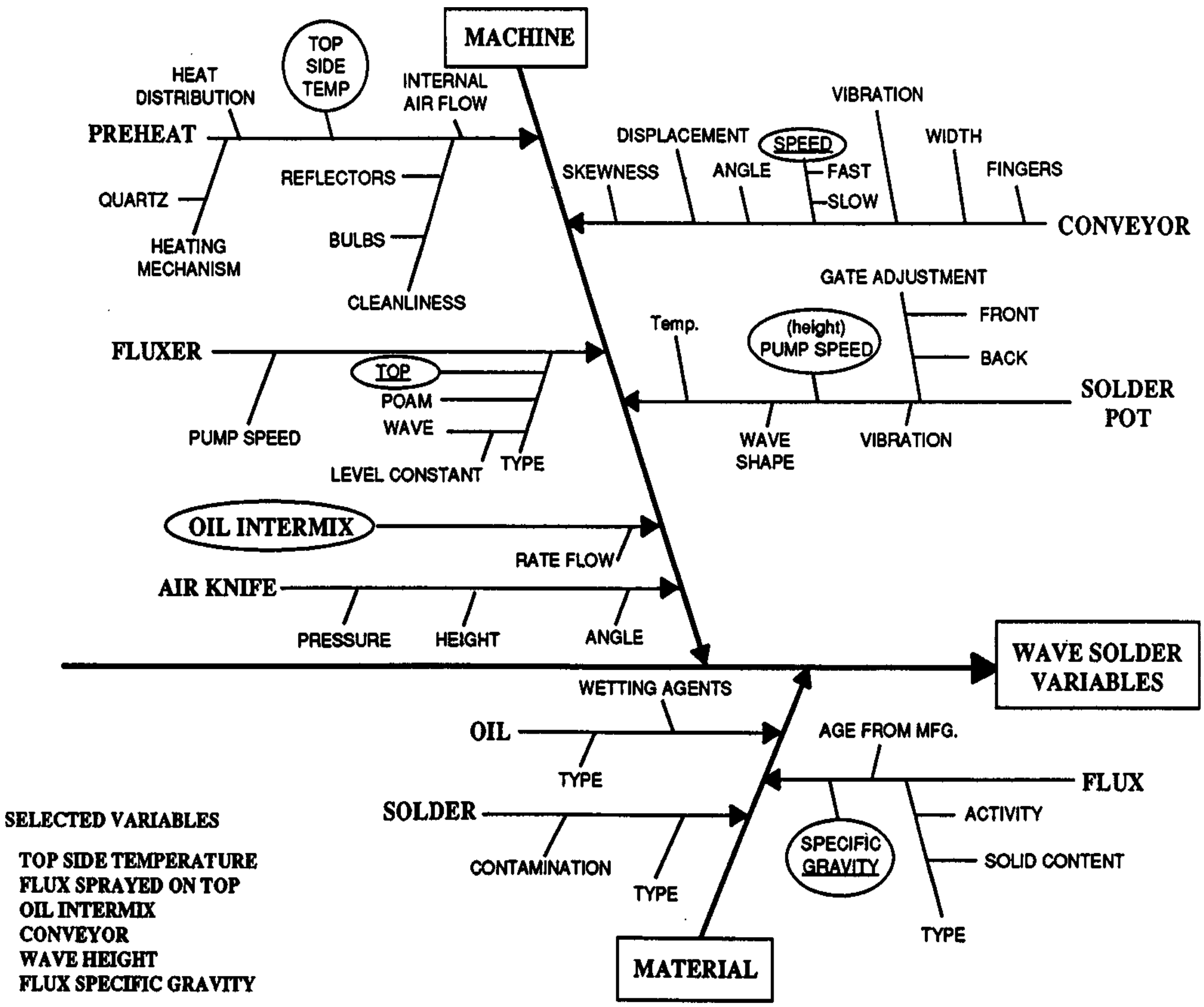

Figure 5-4 Sample of Ishikawa Diagram

The classical approach for DOE was pioneered in the early 1920's by Dr. R. A. Fisher, who devised techniques for running agricultural experiments in the imperfectly controlled conditions of the outside world, rather than in a greenhouse. His methods produced good results in medicine, education, and biology and were quickly adopted in these disciplines. In general, however, managers' understanding and support of DOE in mainstream industry in U.S. and Europe has been limited.

While the classical DOE developed by Fisher was based upon a factorial design, the Japanese have been very successful in using fractional factorial designs and other orthogonal arrays to improve products early in the manufacturing process. Dr. Genichi Taguchi, in particular, has emphasized the importance of DOE in minimizing variations and bringing the mean on target, in making products resistant to variations in components.

<u>Taguchi's Quality Philosophy</u>

Before dealing with Taguchi's DOE techniques, it is important to understand the basic elements of Taguchi's quality philosophy. The following seven points explain these basic elements:

1. An important dimension of the quality of a manufactured product is the total loss generated by that product to society.

2. In a competitive economy, continuous quality improvement and cost reduction are necessary for staying in business.

3. A continuous quality improvement program includes incessant reduction in the variation of product performance characteristics about their target values.

4. The user's loss due to a product's performance variation is often approximately proportional to the square of the deviation of the performance characteristic from its target value.

5. The final quality and cost of a manufactured product are determined to a large extent by the engineering designs of the product and its manufacturing process.

6. A product's (or process's) performance variation can be reduced by exploiting the nonlinear effects of the product (or process) parameters on the performance characteristics.

7. Statistically planned experiments can be used to identify the settings of product (and process) parameters that reduce performance variation.

These seven points do not cover all of Taguchi's ideas. Some of these points have also been made by other quality experts.

Variation Reduction

Perhaps the most important distinction between the conventional and Taguchi's approach to deal with process or product variability is the way the need for variation reduction is perceived. According to the conventional wisdom, no matter how narrowly a parameter falls within specification limits, the user will be 100% satisfied; and no matter how narrowly a parameter falls outside a specification limit, the user will be 100% dissatisfied. Taguchi's approach, on the other hand, surmises that loss occurs not only when the product is outside of specifications, but also when the product falls within specifications. In addition, the loss continually increases as the product deviates further from the target value. While a loss function may take on many different forms, Taguchi has found that the simple quadratic function approximates the behavior of loss in many cases. When the quality characteristic of interest is to be maximized (such as tensile strength) or minimized (such as part shrinkage) the loss function may become a half parabola. The loss function promotes efforts to continually reduce the variation in a product's functional characteristics. Taguchi's method of quality engineering can be used to attain such improvements.

Controllable Factors Versus Noise Factors

To minimize loss the product must be produced at optimal levels and with minimal variation in its functional characteristics. Two factors affect the product's functional characteristics: controllable factors and noise (or uncontrollable) factors. Controllable factors are factors that can easily be controlled, such as choice of material, cycle time, or mold temperature in an injection molding process. Noise factors, on the other hand, are nuisance variables that are either difficult, impossible, or expensive to control.

There are three types of noise factors: outer noise, inner noise, and between product noise. For the injection molding process, the ambient temperature and humidity may be the outer noise; the aging of the machinery and tolerances on the process factors may be the inner noises; while manufacturing imperfections are generally responsible for the between product noise. Noise factors, in general, are responsible for causing a product's functional characteristic to deviate from its target value. The goal is not to identify the most "guilty" noise factors so that an attempt can be made to control them. Controlling noise factors is very costly, if not impossible. Values should be selected for the controllable factors to make the product or process least sensitive to changes in the noise factors; that is, instead of finding and eliminating causes, as the causes are often noise factors, the impact of the causes should be removed or reduced.

Parameter

The tool used to achieve the robustness against noise factors and reduce cost is called parameter design. Parameter design, Taguchi style, involves experimental design techniques utilizing orthogonal arrays and the signal-to-noise ratio. In the United States, most engineers are conditioned to spend money to reach required product performance levels. They jump from system design to tolerance design, often omitting parameter design- the step where they can reduce costs and improve quality most efficiently.

The strategy in Taguchi's experimental design is to recognize controllable factors and noise factors and to treat them separately. The search for interactions among controllable factors is de-emphasized, although there are exceptions. The key to achieving robustness against noise is to discover the interactions between controllable factors and noise factors. Specific interactions between controllable factors and noise factors need not even be identified. As long as the noise factors are changed in a balanced fashion during experimentation, preferred parameter values can be determined using an appropriate signal-to-noise ratio.

Summary of the Taguchi Approach

The Taguchi approach is displayed in Figure 5-5. According to John Vergoz, vice president of technology at the Budd Company in Troy, MI, "A definite benefit to the Taguchi methods is that design engineers and process engineers learn how to talk to each other in a common language." The two groups can quantify the relationships between the manufacturing process and the design requirements.

Vergoz adds that design and process engineers can pinpoint which variables have the strongest functional relationship to product's requirements. The Taguchi methods isolate the effects on the product of adjusting manufacturing variables that can be controlled. The methods isolate the effects on the product of adjusting manufacturing variables that can be controlled. The methods also determine what effect uncontrollable variation in the manufacturing process has on quality.

Vergoz points out three strengths of using the system. First, the methods help determine the functional relationship between those things that can be controlled and the outcome of the process. Second, the methods can be used to move the mean of the process results to the desired position by changing controllable variables. Third, the Taguchi methods determine the relationship of noise - data and variables the cannot be controlled, including the stackup of normal processing tolerances - to the variation in the product as manufactured.

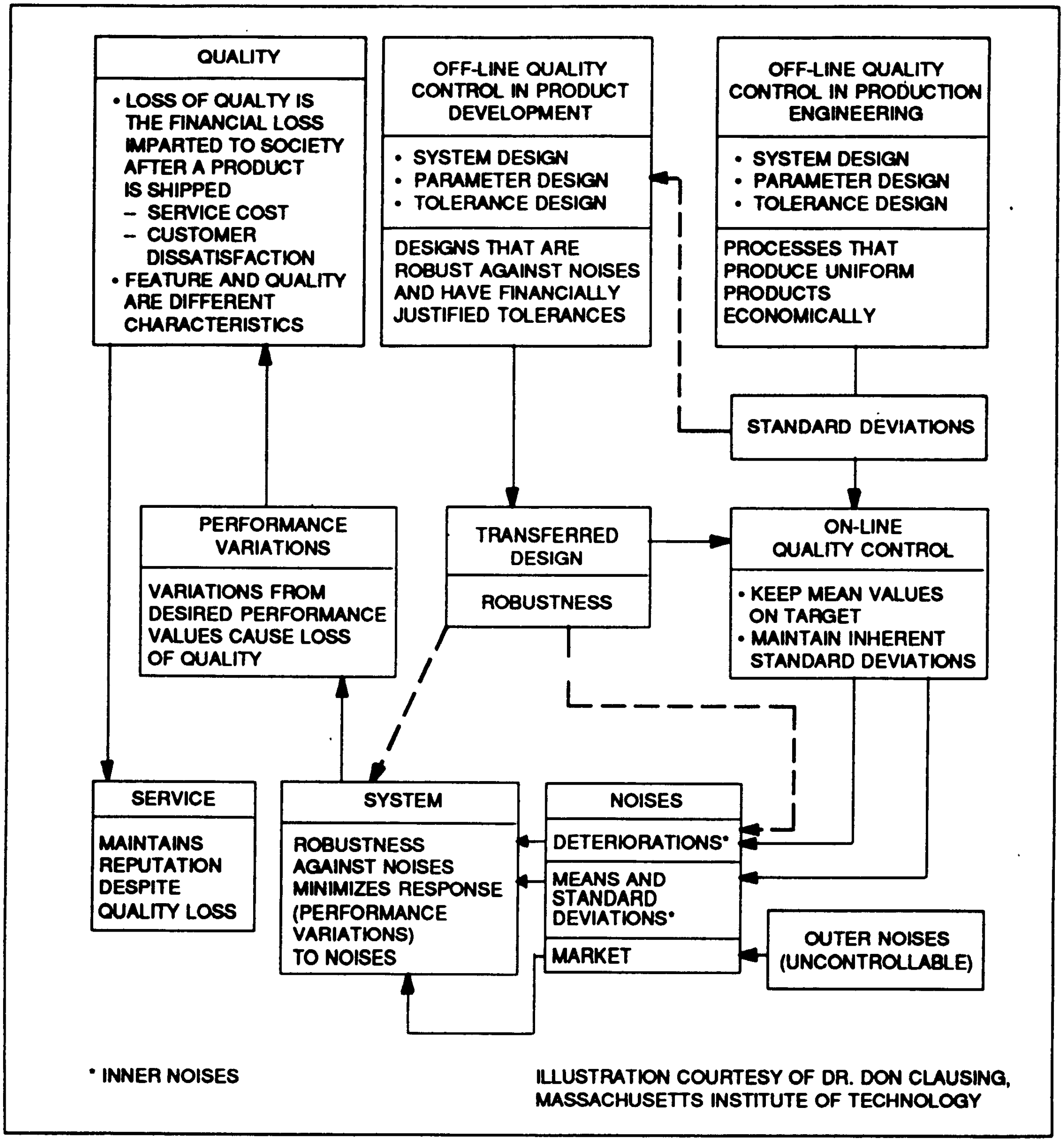

Figure 5-5 Off-line and On-line Quality Control Via Taguchi

Quality Function Deployment (QFD)

Quality function deployment (QFD) is an overall concept that provides a means of translating user requirements into the appropriate technical requirements for each stage of product development and production (i.e., marketing strategies, planning, product design and engineering, prototype evaluation, production process development, production sales). This concept is further broken down into "product quality deployment" and "deployment of the quality function"

The basic idea of QFD originated in Japan and was introduced to U.S. industry by Dr. D. Clausing. Ford Motor Co. and several supplier companies were pioneers in the development of QFD as an operating mechanism to transform customer expectations into specific design and manufacturing requirements. The first U.S. automotive vehicle to benefit from this formalized form of QFD was the 1988 Lincoln Continental. In a recent speech, William E. Scollard, Ford's vice president of manufacturing operations, characterized QFD simply as the means to "build cars for the taker—not the maker."

In the past U.S. industry has concentrated more on meeting company or technical requirements, and less on customer expectations. Now, the task is "How can we deploy customer expectations into technical requirements with all company functions integrated through a common set of work load determinants?" From a hardware standpoint, several U.S. companies (especially Ford) have been very successful in the application of QFD for product improvement; many case studies now available illustrate how matrix charts or binary tables have helped integrate various diverse activities within a company or division.

Key terms most frequently associated with QFD are as follows:

1. The Voice of the User
   The user's requirements are expressed in their own terms
2 Counterpart Characteristics
   An expression of the user's requirements in technical language that specifies user-required quality; counter-part characteristics are critical final product control characteristics.

3 Product Quality Deployment
   These are the activities needed to translate the voice of the user into counterpart characteristics.

4 Deployment of the Quality Function
   These are the activities needed to assure that user required quality is achieved; the assignment of specific quality responsibilities to specific departments. The term "quality function" does not refer to the quality department, but rather to any activity needed to assure that quality is achieved, no matter which department performs the activity.

5. Quality Tables
   These are a series of matrices used to translate the voice of the user into final product control characteristics.

To understand QFD, it must first be understood that the approach to quality is fundamentally different in U.S. and Japanese companies. In Japanese companies, the user's voice drives all activities, while in many U.S. companies, it is the executive's voice or the engineer's voice that prevails. Furthermore, as compared to many U.S. companies, Japanese companies pay more attention to fixing what the user doesn't like. That is, the Japanese put more effort into designing quality at the product design stage, while U.S. companies put a greater emphasis on problem solving.

In QFD, all operations of the company are driven by the "voice of the user"; QFD therefore represents a change from manufacturing process quality control to product development quality control. Kobe Shipyard, Mitsubishi Heavy Industries, Ltd., formalized QFD in 1972, marking the beginning of this movement in Japan.

QFD brings several benefits to companies willing to undertake the study and training required to put the system in place:

- Product objectives based on customer requirements are not misinterpreted at subsequent stages.

- Particular marketing strategies or “sales points” do not become lost or blurred during the translation process from marketing through planning and on to execution.

- Important production control points are not overlooked — everything necessary to achieve the desired outcome is understood and in place.

- Tremendous efficiency is achieved because misinterpretation — of program objectives, marketing strategy, and critical control points — and need for change are minimized.

The QFD system concept is based on four key documents as follows:

1. Overall User Requirement Planning Matrix
   This translates the voice of the user into counterpart control characteristics; that is, it provides a way of turning general user requirements—drawn from market evaluations, comparisons with competition, and marketing plans—into specified final product control characteristics.

2. Final Product Characteristic Deployment Matrix
   This translates the output of the planning matrix—that is, the final product control characteristics—into critical component characteristics. Thus, it moves one step farther back in the design and assembly process.

3. Process Plan and Quality Control Charts
   These charts identify critical product and process parameters, as well as control or check points for each of those parameters.

4. Operating Instructions
   The operating instructions are based on the critical product and process parameters; these instructions identify operations to be performed by plant personnel to assure that important parameters are achieved.

The overall QFD system based on these documents traces a continuous flow of information from user requirements to plant operating instructions; it thus provides what W. Edwards Deming calls “a clear operational definition” — common purpose, priorities, and focus of attention.

PROGRAM MANAGEMENT REQUIREMENTS

The DOD requires that the program management office (PMO) develop and manage quality programs to achieve the specific objectives shown in Figure 5-6.

Current DOD philosophy and procedures recognize that quality is not something that naturally results from the development or improvement of systems and equipment but, instead, is the result of focused effort and attention during program planning, design, and manufacture. To achieve quality objectives in deployed systems, DOD Directive 4155.1 charges the program manager with the responsibility for the development and execution of a program to assure the quality of systems being acquired for use. More specifically, the directive defines quality assurance as a planned and systematic pattern of all actions necessary to provide confidence that adequate technical requirements are established, products and services conform to established technical requirements, and satisfactory performance is achieved.

In developing material for field use, the DOD quality concept is based on three mutually supportive objectives — quality of design, defect prevention, and quality of conformance. Quality of design reflects the inherent capability of the system or product to meet the needs of the user. Defect prevention involves those manufacturing or quality control techniques used to prevent defects in manufacturing or in equipment to be provided to DOD users. Quality of conformance is the measure of the extent to which the physical, real system conforms to the design criteria and the needs of the user.

Quality of Design

The quality of a particular design is the inherent capability of the product resulting from that design to meet user's needs. The objective of the DOD acquisition process is to provide to the operational forces cost-effective products that are mission-capable upon receipt and throughout their operational life. This requirement is integral to the three basic quality of design issues:

- Performance
- Reliability
- Maintainability

Measures of quality of design may be characterized in terms of the emphasis on each of these issues received during design of the complete product — including design effort to reduce exceptional manufacturing or support burdens.

Performance: What is the demonstrated level of military performance of the end system? In this regard, we look to those characteristics that give the item military utility — such as payload, range, effective radiated power, thrust, probability of kill, speed, or any of a vast array of quantitative parameters. The quality of design is reflected in the level of the performance characteristics that can regularly be obtained under field conditions without damage or excessive wear and tear on the equipment. This perspective of the quality of design is intimately related to our military strategy regarding use of technology as a force multiplier and, thus, it is a significant element in successful design evolution.

- ASSURE MISSION AND OPERATIONAL EFFECTIVENESS AND USER SATISFACTION WITH DOD PRODUCTS
- ASSURE THAT ALL SERVICES AND PRODUCTS IN WHICH THE DOD HAS AN INTEREST CONFORM TO SPECIFIED REQUIREMENTS
- ASSURE THAT ESSENTIAL QUALITY AND RELATED TECHNICAL REQUIREMENTS ARE CONSISTENT WITH CUSTOMER NEEDS
- TAILOR CONTRACTUAL QUALITY REQUIREMENTS FOR EACH ACQUISITION IN COMPLIANCE WITH DOD DIRECTION FOR SPECIFICATIONS AND STANDARDS APPLICATION
- ASSURE THAT ALL THE ABOVE ARE COST EFFECTIVE

Figure 5-6 Objectives of DOD Quality Programs

Reliability: How long can the user count on the system to provide utility? Quantitative reliability engineering, as an aspect of quality of design, deals with the duration and probability of failure-free performance under stated conditions. Reliability is a function of the design complexity and the inherent ability of the parts of the system to continue functioning properly under operational conditions. It is influenced by design decisions on quantitative issues such as stress levels, design margins, part selection, part simplicity, redundancy, and operating temperatures. When the system as designed interacts with its use environment, the inherent reliability of the design is the basis for prediction of the duration and probability of failure-free service — assuming that the design has not been degraded by the manufacturing processes. In this sense, the quality of design can be viewed as a boundary because the system, as produced, cannot be better than the theoretical quantitative quality of design.

Maintainability: What is the likelihood that the system can be retained in or returned to its specified capability while in the use environment? The maintainability of a system is a measure of the level of difficulty involved in retaining, through preventive maintenance, or restoring, through repair or replacement, function to the system when maintenance is performed by personnel having prescribed skill levels, and using defined procedures and resources. Maintainability of the design measures such quality of design choices as complexity, accessibility, and testability in the installed condition. The measures provide a quantitative relationship among quality of design decisions and the resulting skill level requirements, special equipment requirements, and related resource requirements for resolving test, repair and other similar issues.

The combined effect of the inherent reliability and maintainability quantifies the operational availability of the system. By "availability" we refer to the proportion of time in which the system is capable of performing its defined mission. Where the availability inherent in the design is low, it can be improved by special support and maintenance action or by restriction on system use, but these actions incur penalties in cost to support the system. Reliability and maintainability emphasis in design means that an operational availability approach to quantifying system parameters can result in higher quality of design than a fragmentary suboptimized approach would produce.

In developing designs that will exhibit the requisite quality, the PM office must continually evaluate the design as it evolves to determine the adequacy of contractor attention to quality issues and to determine the expected level of the resulting quality of the design. In their participation in the design process, the PM office should focus on the quality characteristics of the design. A quality characteristic can be defined as a basic element that is determined to be one of the requirements for arriving at a configuration or design that will satisfy the user need or mission involved. In one sense, all of the descriptors and characteristics of the design could be defined as quality characteristics, since the eventual performance is a composite of all the design details. This definition is too cumbersome to be of value in prescribing design review activity. The PMO should limit the field of definition to only that set of design elements or features that have quantitative and theoretically auditable impact on the system's performance and availability. This set could include issues such as parts' relative stress levels, materials, test parameters, dimensions and tolerances, grade of parts used, system and subsystem complexity, controlled manufacturing processes, system producibility, and inspectability. These elements represent characteristics that must be controlled during the production of the system to ensure that the quality of conformance is not degraded.

QUALITY ASSURANCE

The quality of DOD materials and equipment is the responsibility of every person involved in the acquisition and management of DOD materiel. The issue of product quality must be a central issue from the program initiation through the production and deployment phase of the life cycle. Within DOD, the "Quality Concept" illustrated in Figure 5-7, consists of quality of design, prevention of defects, and workmanship. The interrelationship of each is suggested by the size of each cell and its border relationship to the adjacent cell.

The quality of design effort begins with the Concept Exploration/Definition phase of the program life cycle, continues through Full-Scale Development, and many times continues into production and even redesign after deployment. Often mistakes in design are revealed due to production problems encountered when production is attempted or when customer complaints report problems relating to quality of design.

Defect prevention starts with the first development-production planning, and continues through the operation and deployment phase of the life cycle. Figure 5-8 shows the relative savings attainable by early focus on product quality. Workmanship is normally associated with the initial production efforts and continues throughout the production phase. Any time a problem in quality becomes evident, the required corrective action must be taken to correct or fix the problem and its causes.

DOD Directive 4155.1, Quality Program, provides broad and general policy for the implementation of quality programs throughout DOD.

Quality of Conformance

The production phase of the acquisition process has a major impact relative to quality characteristics. Quality of conformance becomes a reality or a failure as the result of production efforts. The manufacture, processing, assembling, finishing, and review of the first article and first production units, is where failure or success in the area of quality of conformance is first measured. The original design quality characteristics can be easily altered in production. Any operation which causes the characteristic to be outside of the specified limits will render the configuration of the product different from that which was originally intended. This sometimes results in the granting of waivers, deviations, or changes which may alter the fitness for use.

A quality program requirement in accordance with MIL-Q-9858A is used on major system acquisitions, in addition to a standard inspection requirement. MIL-Q-9858A requires the contractor to establish and maintain a quality program acceptable to the government in accordance with the military specification. This requirement is established when the technical require control of work operations, in-process requirements to the contract are such as to controls and inspection, as well as attention to other factors (e.g., organization, planning, work instructions, documentation control, advanced metrology).

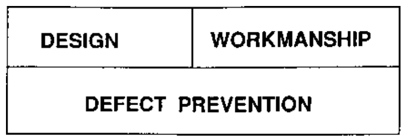

Figure 5-7 DOD Quality Concept

MIL-Q-9858A requires the contractor to develop written procedures and make them available procedures before beginning production under the contract.

<u>Contract Administration Office Role</u>

In addition to specifying the proper contract quality requirement, the contract must also stipulate the place of performance of government acquisition quality assurance (Government source inspection) and the place of acceptance of the supplies or services. When government quality assurance actions are at source, the Contract Administration Services (CAS) element has the responsibility for assuring contractor compliance with all of the contract provisions including the contract quality requirements. Normally, the Defense Logistics Agency (DLA) is the CAS element responsible for contract administration, and DOD Directive 4105.59 provides a list of assignments. Plant cognizance may be assigned to the Army, Navy, or Air Force if they have predominant interest at a contractor’s plant. The CAS component

Quality Assurance Representative (QAR), who is assigned the responsibility for the contractor facility, is the individual charged with responsibility for assuring that the contractor complies with all contract quality requirements, including evaluating and determining the acceptability of contractor’s inspection system or quality program, and for performing product inspection to assure quality of conformance.

<u>Quality Feedback</u>

The last element which affects the product quality is the feedback after the item is in use. The results of the design and manufacturing efforts receive their real test when the item or system is actually placed in use. If all of the prior efforts have not been adequately performed, the resulting product may fail to meet the user’s needs. The goal is to strive for no failures and full user satisfaction. If this is not achieved, there is still the potential for correction to remove the cause of failure and of the user discontent. Of course, this is most difficult at this late stage of the acquisition cycle. Engineering changes after this point cost more to implement than those discovered during initial design; therefore, it is important that all quality actions take place during design, development, and manufacture of the product.

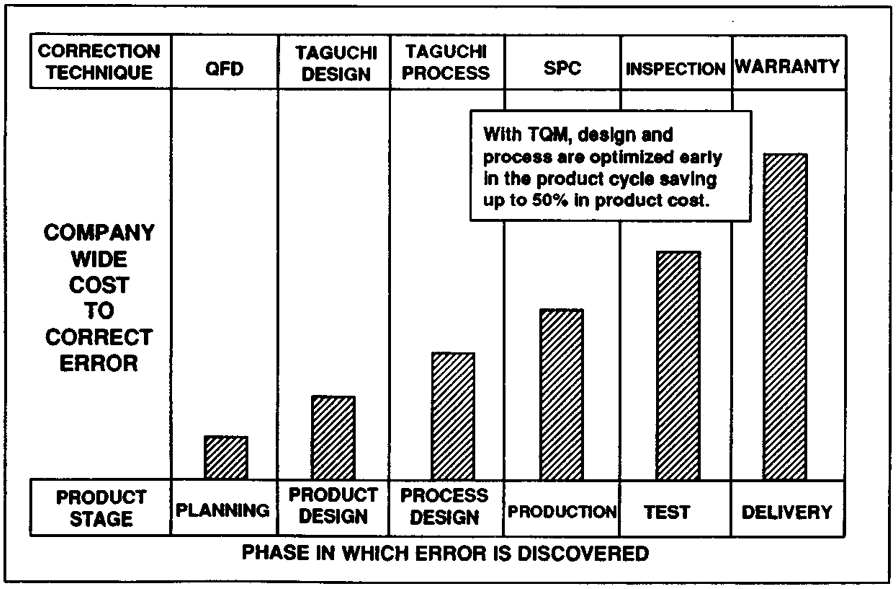

Figure 5-8 Potential Savings

RELIABILITY AND MAINTAINABILITY

DOD's policy on weapons system reliability and maintainability, as outlined in Directive 5000.40, July 1980, rates operational availability as equally important as operational performance, and requires managers of military development programs to ensure that reliability factors are engineered into their systems from the earliest design phase.

The shift in DOD emphasis from performance as the single measure of a weapons system's effectiveness to one of performance set against a backdrop of the total life cycle cost of ownership has been an evolutionary process. The DOD Directive is an internal document that establishes the Defense Department's policy on reliability and maintainability, and will be used to convey that policy down to the level of systems program managers in the individual services.

The DOD reliability and maintainability policy has five major objectives as shown in Figure 5-9.

The intent of Directive 5000.40 is not only to inject reliability and maintainability into the early engineering phase but to document the achievement of required standards by establishing a series of reliability goals and thresholds for the program managers to meet from the start of the engineering and development process.

Reliability of Design

Reliability focuses on the issue of the duration or probability of failure-free performance under stated conditions. It is generally recognized that system reliability is a direct function of the system design and that success in achieving reliability in fielded systems is a result of two factors: attention to reliability during the design phase and testing to measure attained reliability as part of a planned reliability growth program.

- INCREASE WEAPONS SYSTEM READINESS AND MISSION SUCCESS RATIOS
- REDUCE THE MILITARY SERVICES' MAINTENANCE AND LOGISTICS SUPPORT COST
- LIMIT THE MANPOWER NEEDED FOR MAINTENANCE AND SUPPORT OF ADVANCED WEAPONS SYSTEMS
- PROVIDE DOD MANAGERS WITH FEEDBACK INFORMATION ON THE PERFORMANCE OF WEAPONS SYSTEMS UNDER OPERATIONAL CONDITIONS
- ENSURE THE BEST RETURN ON INVESTMENT IN TERMS OF OPERATIONAL CONDITIONS

Figure 5-9 Major Objectives of DOD Reliability & Maintainability Policy

There is a growing emphasis on the need to make reliability issues a more visible part of the design process. This emphasis reflects a recognition that reliability of the system is a basic function of the specific elements of the design, and that post-design fixes are an inefficient mechanism for achieving reliability targets. Some of the specific reliability activities which should be considered during design phase include:

- Failure Mode Effects Analysis: providing an evaluation of each potential mode and mechanism of failure, probability of occurrence and probable effect on performance.

- Apportionment of Reliability Requirements: establishing the necessary subsystem, equipment and part reliability required to meet system requirement.

- Parts Derating: the use of parts with specified performance characteristics much greater than the performance limits by the design.

- Parts Control and Standardization: minimizing the number of different part configurations and using parts with known performance.

- Design Simplicity: using the minimum number of parts, thus reducing complexity.

- Minimized Terminal and Component Temperature: reducing thermal stresses.

- Redundancy: assuring mission success in the event of single system failure.

- Increased Safety Margins: allowing for continued performance in over-stress situations.

These activities may lead to design solutions which invoke penalties within other design measures such as cost, weight or performance. The ultimate objective of the design process is to achieve, through appropriate trade-off, a balance between operational effectiveness and ownership cost.

<u>Reliability Testing</u>

An additional area of importance to the PMO is the requirement that programs include provisions for demonstration and test to show that the quantitative requirements have been achieved.

Reliability testing and the evaluation of test data provide tangible results concerning the reliability of design. The results of conducting the analyses based on test data are thus very critical since they serve as the cornerstone for many decisions such as design adequacy, assurance that reliability under field conditions will be adequate, and the need for design changes. The utilization of test data for reliability analyses must be very carefully planned and evaluated.

In general there are two categories of tests which can be used to provide information for supporting evaluations. These are the measurement tests (i.e., tests designed to measure reliability), and evaluation tests (i.e., tests which generally result in a regression analysis designed to evaluate relationships between environments or stresses and parameters which influence the reliability of an item). Properly used, both categories of tests can be used to provide information for monitoring reliability progress or for identifying the potential areas where greater concentration is required to achieve objectives. However, it should be pointed out that the approach to planning, analysis, and use of results depends, in a large measure, on the category of test being conducted.

Since test data can be extremely valuable in monitoring, it is important to be able to identify the types of tests that are often applied. These tests, shown in Figure 5-10, can frequently be used as sources of reliability oriented information, provided of course that planning has been such that the appropriate reliability data will be recorded along with information normally obtained from these tests:

It should be pointed out that the assurance of reliability program effectiveness requires a continuous monitoring and evaluation based on various data developed either through design analysis or through test. A considerable amount of test data, which is particularly useful as a means of evaluating reliability and maintainability, can often be made available in early stages of a program through proper planning and utilization.

Reliability Growth

Reliability growth is a function of the maturity of design and the application of engineering and test resources. It provides visibility to the decision-makers of how reliability is improving throughout the program. In general, reliability growth is the result of an interactive design process. As the design of various items/systems matures, the designer identifies actual or potential sources of failures and proposes product redesign or manufacturing process improvements to resolve problems.

Reliability growth assessments (Figure 5-11) are used in controlling the growth process through examination of reliability growth curves which are generated and maintained for the items under consideration. Reliability growth curves (Figure 5-12) show both the planned and assessed growth, and a comparison of these values will indicate program progress. On the basis of these comparisons, the contractor or PMO can develop appropriate strategies involving reassignment of resources or adjustment of time frame. The monitoring of reliability growth involves comparisons of the on going activities against the applicable reliability program plans. The activities are monitored to establish whether performance conforms to the management plan. An additional area of importance of reliability monitoring is the design review at various stages of the development effort to determine whether the product design adheres to the expressed and implied performance requirements.

Reliability in Manufacturing

The reliability of the as-built product is bounded by the inherent reliability of the design. In achieving design reliability in the manufactured product, it is critical for the design team to specify the physical and functional requirements which must be achieved in the parts and components. Whenever possible these requirements should be described in a manner that will allow in-process control during manufacture. These requirements should be included in the company's quality planning for both in-house and subcontractor manufacturing.

- QUALIFICATION TEST
- PREPRODUCTION TEST
- LOT ACCEPTANCE TEST
- INDIVIDUAL ACCEPTANCE TEST
- CRITICAL WEAKNESS RELIABILITY TEST
- TEST TO FAILURE

Figure 5-10 Typical Tests Yielding Reliability Information

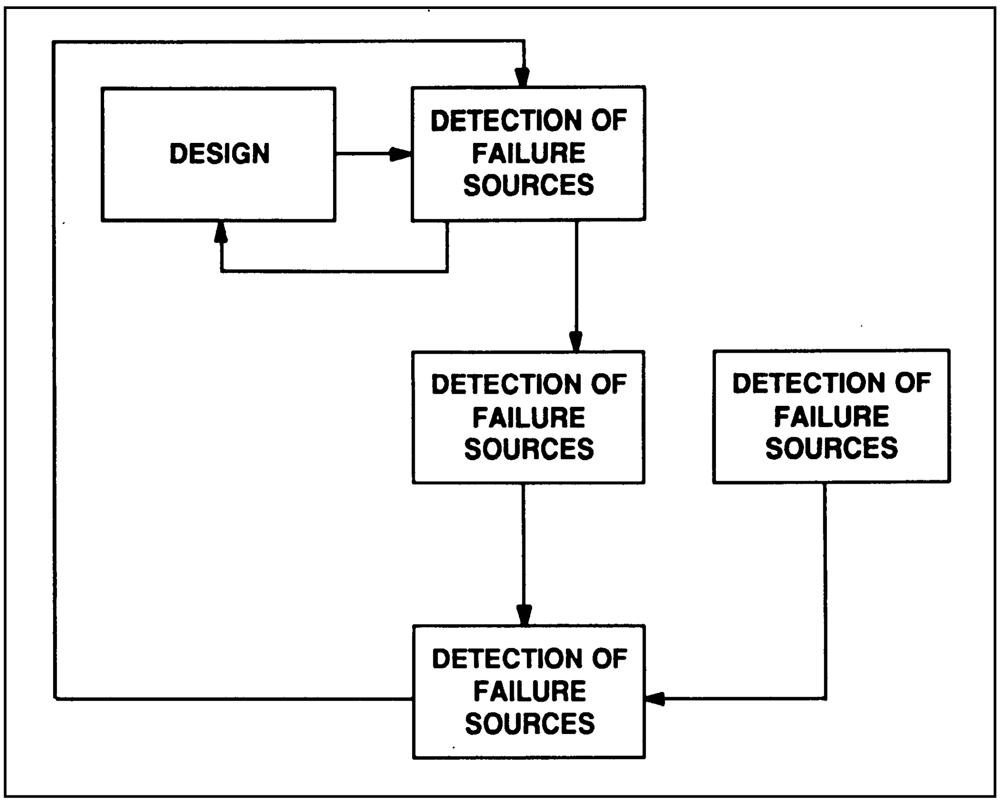

Figure 5-11 Assesment of Reliability Growth

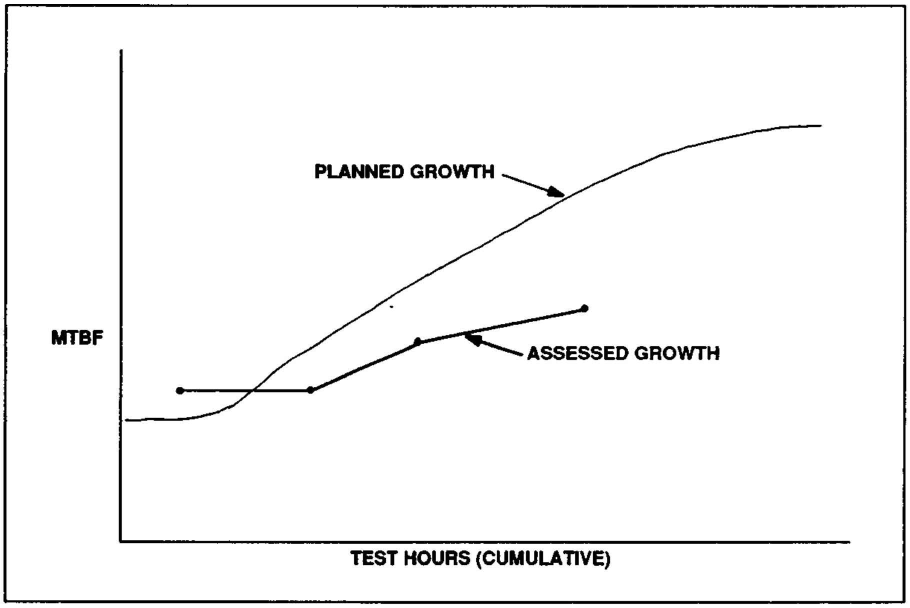

Figure 5-12 Reliability Growth Curve

Even where the controls above are specified, there is some risk that reliability of the hardware may be degraded by changes in tooling, processes and work flow. These types of changes are a normal part of most manufacturing programs. To assure that these changes do not have a negative impact on hardware reliability, Production Reliability Acceptance Testing (PRAT) can be required by the PMO. These tests are accomplished on delivered or deliverable production items under specified conditions, to assure that the manufacturer has complied with the specified reliability requirements. The PMO must specify the particular items to be tested, the test duration, frequency and test plan and environment. In addition, focused emphasis on continuous process improvement can yield significant improvements in achieved reliability and quality.

Reliability and Maintainability Quality Team Concept

Because of its potential value, it is important to briefly describe the Reliability and Maintainability (R&M) quality team concept which has been used successfully. The new concept is the idea of Major James F. Guzzi, when he was serving as R&M Manager for the C-17 Aircraft being developed by Douglas Aircraft Company as the airlifter of the future. The concept uses R&M Quality Teams and a Review Council.

Industry's approach to building a weapon system — a complex engineering and manufacturing task — emphasizes the need to recognize and understand the dynamic process that defines total system R&M. Any program organization must be innovative in its approach to achieve the desired understanding of this process. R&M are always addressed; however, today the need to achieve better R&M can be enhanced by a new integrated approach. The technology and management system are equal partners in this effort.

The R&M Quality Team concept provides an enhancement of the R&M management approach during the Full Scale Engineering Development phase of a weapon system program and does not disturb the integrity of the organization. During this phase, the design requirements of the weapon system are engineered "in" and the resultant inherent R&M characteristics and the related combat capability are "locked in".

With the focus being placed on the importance of R&M, the opportunity to do it right the first time becomes the challenge for both industry and the government who work as a team to meet the goal. The team approach provides an atmosphere of understanding for a win-win solution.

In multi-functional organizations, the objective to achieve system R&M requirements requires that the organization use a system engineering approach that has a focus on system level R&M design requirements throughout the total development process. The system R&M concept allows an organization to successfully manage the R&M efforts across the total design organization.

The basic premise of the R&M Quality Team concept supports the R&M design process and the need to provide an innovative approach to enhance the management of system R&M during the design process. The following basic assumptions provide a foundation for an understanding of the development of the concept.

-R&M is co-equal in importance to cost, schedule and other performance factors.

-R&M is a total system design process that affects the whole organization.

-The management of R&M is not the responsibility of a single function. It is the responsibility of the organization to "manage" the system approach to R&M through the integration of all functions.

-Management commitment drives the program, provides guidance and control, and ensures R&M requirements are met.

A system level management approach is used to achieve the R&M design goals through the leadership of its members. The effective manager understands the dynamics of team communication and effectively carries out these tasks. In addition to team management, information dissemination is a critical factor and must also be clearly carried out. Once established, communication and information influence changes and allow enthusiastic workers to establish and reach individual, team, and organizational goals. A total system level process allows feedback and insures a team solution will be successful. The method of team solution can be defined as participative or power-sharing concept, the R&M Quality Team concept achieves equality with the other factors in the solution.

Participative decision making (PDM) is straight forward — a mode of joint decision-making in a participative, focused climate. Decisions are made by a group of people with each member of the group making an input to the final decision. It is truly a system engineering approach. PDM is also considered as a continuum with managers varying the level of team and individual participation according to immediate task requirements, participation characteristics, situational conditions, and likely task outcome. R&M Review Councils and Quality Teams are designed to use PDM to achieve integrated solutions.

An R&M Quality Team concept has been conceptualized and developed to focus management attention on the system level R&M process during Full Scale Engineering Development. The concept is simple, but well founded, and it provides a powerful means to streamline and enhance the communications and system engineering process in a total organization. This concept has provided the capability for a directed response to system R&M problems while creating an atmosphere for system change. The approach facilitates R&M engineers and systems designers to work as a chartered team under the guidance and direction of an R&M Review Council.

The R&M Quality Team concept, which is defined in Figure 5-13, establishes and integrates the lines of communication among the functions of the Review Council shown in the vertical direction in the figure and in the horizontal direction by the Quality Teams. This process creates a R&M management network within an existing organization. Activity is managed by the Review Council to insure that the "focus" is not diluted in the functional activities and insures that R&M is part of the design effort. In essence, the concept creates a system engineering approach that drives the R&M goals to meet the total system level requirements.

Through enactment of an R&M Quality Team concept, management commitment is built-in and the necessary focus to provide the most R&M for the process is assured. The results to date using this concept have been very impressive and have demonstrated a potential for enhancing the acquisition process for a weapon system. The concept provides the invaluable ability to effectively manage transition of a program from development to production. For example, the concept links design to manufacturing through the Review Council and the team interactions. Further, it provides an R&M focus throughout the production process and this translates to production quality.

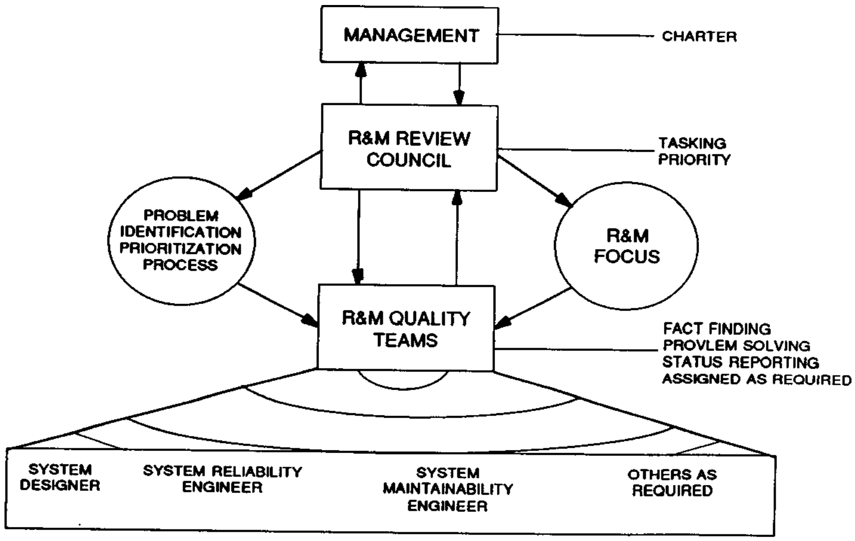

Figure 5-13 Reliability and Maintainability Quality Team Model

TOTAL QUALITY MANAGEMENT INTEGRATION

There are a number of related efforts which can make major contributions to achieving TQM objectives. As the program plans in these areas are developed, attention to the TQM principles and objectives is necessary to maximize the impact of TQM on the acquisition process.

Concurrent Engineering

Concurrent engineering is a systematic approach to product design that considers all of the elements of the product life cycle. Concurrent engineering defines the product, its manufacturing process and other required life-cycle processes such as maintenance.

The advantage of concurrent engineering is illustrated in Figure 5-14. See Chapter 11 for an additional discussion about Concurrent Engineering.

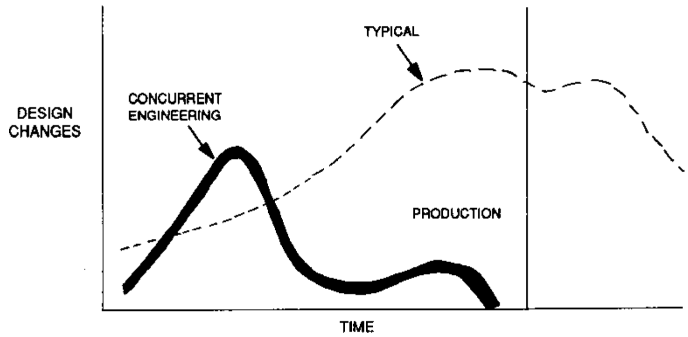

Figure 5-14 Concurrent Engineering Approach vs. Typical Approach

Quality in the Source Selection Process

The procedures used to award contracts have traditionally focused on the lowest bid. While this approach enhances competition; quality is not always given adequate consideration. To further compound the problem, past history of performance does not always play a role in determining eligibility for contract award. In other words, contractors with poor performance history may continue to compete on an equal basis with contractors who are more capable of producing quality products and who have a good reputation in dealing with the government.

Recent changes to the Federal Acquisition Regulations make quality a factor in the source selection process. The intent is not to exclude any potential bidder, but to raise the quality consciousness of those companies/suppliers who plan to bid on a newcontract, and to give due consideration to those companies/suppliers with a good record and with products and services that reflect the application of continuous quality improvement techniques. Through this approach, the acquisition cost is placed in the proper perspective as related to the total cost of product ownership.

Industrial Modernization Incentive Program

The Department of Defense IMIP is a joint venture between government and industry to accelerate the implementation of modern equipment and management techniques in the industrial base. An IMIP is considered when competitive market forces are insufficient to motivate independent contractor modernization. An IMIP can also be implemented when significant benefits such as cost reduction, elimination of production bottlenecks, improved quality, reliability, maintainability and improved surge capability will result.

The short term IMIP objectives are to reduce defense costs and lead times and increase the quality of manufacturing through productivity gains. The long term objective is a strong responsive industrial base capable of meeting current needs as well as surge and mobilization requirements.

Benefits of IMIP can be measured in terms of stimulating capital investments, increasing manufacturing flexibility and production capacity to respond to defense requirements, and realizing savings throughout the life of a more reliable weapon system that is produced in modern facilities. IMIP offers contractors the opportunity to pursue something that under “business as usual” conditions, would be unacceptable financially, or too risky technically. The program is expanding and in the future it will take on a broader focus in the DOD support infrastructure.

Warranties

Much has been said about warranties in the context of providing assurance of quality. Warranties are used successfully in the commercial world, and they do present a good tool in our quest for quality. As contrasted with the commercial market, however, the majority of DOD purchases are for unique equipments and systems produced in small quantities. Moreover, these equipments are handled and serviced by government personnel and, considering the number of people involved, the complexity of the supply system, and the various performance requirements that cannot be readily tested, it becomes very difficult to effectively administer warranties.

The primary intent for using warranties should be to motivate contractors to improve the quality of their products, so that they would reap financial benefits by avoiding the warranty cost of repairs and replacements. Warranties are no substitute for quality, and should not be used as a crutch. Simply put, when a system fails to accomplish the mission for which it was intended, the warranty can never compensate for potentially devastating results.

Acquisition Streamlining

Acquisition streamlining is a major initiative directed at the development of realistic and cost effective contract requirements. The program objectives are to reduce the time and cost of weapon system acquisition, and to improve quality. It ensures that only the necessary requirements are imposed during each acquisition phase through tailoring of military standards. This approach gives program managers greater latitude to defer imposition of military specifications and other detailed “how to” contract requirements until industry has had the opportunity to recommend the most technically appropriate and cost effective approaches.

Efforts are underway to enhance streamlining policies to encourage early analysis and tradeoffs to weapon system cost and performance, in order to achieve the best value for the DOD. The military departments and industry are working together to identify outdated and unnecessary military specifications and standards, and come up with better procurement documents that are compatible with new technology. A recent survey indicated that streamlining is resulting in significant reductions in lead time and cost of weapon system acquisition, as well as enhanced quality due to better understanding and timely imposition of requirements.

Value Engineering

Value engineering is a systematic effort directed at analyzing the function of systems, equipment, facilities, services, and supplies, to achieve essential functions at the lowest life-cycle cost without compromising the required performance, reliability, quality, and safety. Value engineering is also used to improve quality and reliability, thereby achieving additional long term benefits.

The DOD Value Engineering Program has two elements: one is the in-house activity performed by DOD personnel; the other is the DOD contractor program. Both elements have provided financial rewards. During the 1986 fiscal year, the in-house program yielded approximately one billion dollars in savings, while contractor proposals amounted to an additional savings of $450 million.